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Abstract

Plant deaths arise from failure when firms exit an industry. Plant deaths are also associated with renewal when incumbent firms close down plants and modernize their production facilities and start-up new plants.

The rate of plant deaths affects the amount of change that occurs in labour and capital markets. Plant deaths result in job losses and incur significant human costs as employees are forced to seek other work. The death process also gives rise to capital losses—to the loss of earlier investments that the industrial system had made in productive capacity. This paper makes use of the plant-death date to provide new information on the likely length of life of capital invested in plants.

This paper measures the death rate over a forty year period for new plants in the Canadian manufacturing sector. It develops a profile of the death rate for entrants as they age. On average, 14% of new plants die in their first year. Over half of new plants die by the age of six. By the age of 15, less than 20% are still alive.

As a result, manufacturing plants have relatively short lives. The average new plant lives only nine years (17 years if the average is employment-weighted). These rates vary by industry. The longest length of life (13 years) can be found in two industries—primary metals and paper and allied products. The shortest average length of life (less than 8 years) occurs in wood industries.

Keywords: plant closures, capital stock

"Like human beings, firms are constantly being born that cannot live. Others may meet what is akin, in the case of man, to death from accident or illness. Still others die a 'natural' death, as men die of old age."
Schumpeter (1939, 69)

1. Introduction

Competition is a dynamic process. It involves the emergence of new firms, their growth, their eventual decay and ultimately the death of those who do not innovate and reinvent themselves. The pervasiveness of this phenomenon has caught the attention of economists from Marshall (1920) to Schumpeter (1939) and many others.

Economists have focused considerable energy to understanding the effects of competition. Less attention has been devoted to examining the nature of the process that underlies competitive forces. This paper examines one aspect of this process—the death of industrial units.[1]

The death of industrial units is the final stage in a life-cycle—one that may either have been brutishly short, as is the case for the majority of entrants, or one that may mark the passage of an era dominated by a mature producer that has been unable to adapt to changing circumstances. The death of producers marks a transition as resources are reallocated from one use to another.

These deaths have consequences. They result in job losses and substantial human costs as employees are forced to seek other work. Employees who are forced to move to jobs in new plants often face periods of unemployment and, in many cases, take up new positions that often pay less than those jobs that they left (Carrington, 1993; Jacobson, Lalonde and Sullivan, 1993).

The death process also leads to capital losses—to the loss of investments that the industrial system had earlier made in productive capacity. Resources that had been used to make equipment or to construct plants to house machinery are lost. The capital that has been invested in a plant that is suddenly shut down loses some, or most, of its value. And this process of exit has consequences in terms of the amount of capital that the industrial system has available to it.

The consequences of this forced adjustment have long interested scholars of business-cycle dynamics.[2] The forced retirement of capital reduces the wealth of those who owned the capital. These losses can affect the stability of financial institutions, consumer sentiment, and the stock of productive capital in the economy that is available to workers.

The purpose of this paper is not to focus on all of the costs associated with plant death. The paper asks only how the information on plant closures can inform the debate on the length of life of an average plant for the estimation of capital stock. Capital stock estimates of manufacturing plant are derived from assumptions about the physical length of life of plant—not the economic life of

1. For a comprehensive overview of Canadian entry, exit and change in incumbent firms, see Baldwin (1995).
2. See Schumpeter 1939; Marx 1966.

that plant. In this paper, we estimate the economic life of an average new plant in manufacturing in order to bring to bear additional information to inform the debate on the appropriate depreciation rates that might be used in this area.[3]

2. *The effect of plant closure on the capital stock*

Most estimates of capital stock are built up from estimates of investment flows using the perpetual inventory technique. Using this technique, capital stock is represented as the summation of the past flows of investment—where the sum is taken over the expected length of life of the asset. Thus gross capital stock in period t is estimated as $K_t = \sum_{i=t-n}^{t} I_i$, where N is the length of life of the asset. Estimates of capital invested in a particular asset such as buildings then only require that annual investments be measured and that an estimate of the length of life (N) be derived. N is normally estimated with some physical concept in mind. The length of life N is taken to be the length of life over which the asset can be used before it becomes physically expended or before it wears out. These estimates generally make use of engineering concepts such as useful service lives to devise estimates of length of life.

The engineering concept is inappropriate if the economic system causes assets to be discarded or to lose most of their value prior to their being worn out. It was Marx (1966, vol. 1.381) who was intrigued by the notion that "competition compels the replacement of the old instruments of labour by new ones before the expiration of their natural life."

The death of producers suddenly causes sales of existing assets in second hand markets. Used assets that are made available as the result of a plant closure are not useless. However, because of asset specificity, their value is probably well below that which the perpetual inventory technique would ascribe to these assets at the time of closure.[4] Consider, for example, a building especially designed for a particular industrial application. That building will have to be refit to handle new tenants. And if the industrial application is far removed from the original use, those costs are likely to be substantial. Steel plants do not make good petroleum refineries. And the fungibility of plants in other types of industries ranges from imperfect to non-existent.

This suggests that the length of life of producers needs to be factored into the calculation of capital stock. The first step in this process is the calculation of the average length of life of a producer. This estimate, in turn, can be obtained by looking at the death process, the topic of this paper.

3. See Gellatly, Tanguay and Yan (2002) for a discussion about the connection between length of life and depreciation estimates.
4. See Ramey and Shapiro (2001) for a discussion of used asset prices in aircraft manufacturing.

3. Research strategy

In order to study the death rate of manufacturers, we make use of data on new plants that were born over the period 1961-99 in the Canadian manufacturing sector. For this study, we examine the death rate of plants, not firms, because we are interested in knowing the average length of life of production facilities. Plants die both because firms die and because incumbent firms shut down production facilities. We are interested in both aspects of plant closure and so combine the two in this study.

We use new plants that are created over this period to estimate the average length of life of a plant since conceptually this is the most appropriate method for tracking a life-cycle. Practically, this method may provide a biased estimate if plants live longer than the period used for study. If so, we will not observe the length of life for many plants in the sample. But our choice of a forty-year period reduces this problem. As we shall see, over 98% of new plants in our sample, have ended their life by the age of 40. An earlier paper by Baldwin and Brown (2004) shows that Canada's manufacturing sector substantially renews itself over this period.

4. Data

In order to examine the incidence of plant closure, we make use of a longitudinal file derived from Statistics Canada's Census (now Survey) of Manufactures program.[5] This program essentially provides census coverage (using a combination of surveys and administrative data) for the population of manufacturing plants—above a certain threshold level.

As is the case for all administrative files, the data contained therein have both strengths and weaknesses that need to be made clear at the onset. First, the file was designed in such a way that it provides quite accurate estimates of the birth and death process. This is made possible by the existence of identifiers attached to each production unit that do not change in a capricious fashion. Identifiers generally disappear (that is, are removed from the database), only when the unit has ceased production.[6] This facilitates the use of this file for entry and exit studies. In this study, a plant death or plant closure is associated with the cessation of operations—that is, the plant no longer exists in the manufactures file or no longer has positive sales.[7]

The file also covers quite a long period of time—from 1961 to 1999—on a consistent SIC basis. The existence of annual observations allows short-term behaviour to be tracked. The long time period that is covered by the database permits studies of industrial dynamics over very long periods. This is important because of the one shortcoming in the file that is common to many databases derived from administrative files. Variations over time occur in the accuracy of individual databases—as the Statistical Agency wrestles with budgetary constraints or a temporary loss in the sources of information being used for the establishment of sampling

5. It is now called the Annual Survey of Manufactures (ASM).
6. For a discussion of this issue, see Baldwin (1995) as well as Baldwin, Beckstead and Girard (2002).
7. A small number of plants stop operations and then restart several years later. In this study, these plants are considered as continuers.

frames. In this study, we overcome this challenge by using all years that are available to us and by averaging our results across entry cohorts. As a result, we have 39 years to calculate the exit rate of the first year of entrants, 38 years for the second year, and so on.[8]

5. *Results*

5.1 Death and survival rates

The first measure examined is the death rate of a group of entrants (an entry cohort). The death rate for the period from t to t+n is defined as

$$R_{t+n,t} = E_{t+n} / N_t$$

where E_{t+n} is the number of deaths in year t+n of a group of entrants who arrived in year t. These rates for all entrants between 1961 and 1998 are averaged and reported in Table 1.

The death rate of new manufacturing plants is quite high (Table 1, column 1). On average, about 14% of new plants die in their first year. The death rate falls monotonically in subsequent years (Figure 1). Another 11% die in their second year. By the 5[th] year, the death rate declines to 6%; by the 10[th] year, it stands at only 3%; by the 20[th] year, it is about 1%.

Despite the decline in the death rate, the cumulative rate of death for new manufacturing plants increases quite rapidly (Table 1, column 2). The cumulative death rate in any year is simply the sum of all plants that have been shut down by that year. The cumulative death rate of a group of entrants in year t over the subsequent n years is:

$$CR_{t+n,t} = \sum_{t}^{t+n} E_i / N_t$$

where E_i is the number of deaths in year i for a group of entrants who arrived in year t.

Some 25% of a cohort of entrants is gone by their 2nd[th] year, 53% of a cohort has exited by their 6[th] year, and 80% die by their 15[th] year (see Figure 2 and Table 1).

8. This does mean, however, that our estimates of death rates at the tail of the distribution (i.e., for higher ages) have less precision since they entail fewer observations.

Table 1. Exit rate of new manufacturing plants (1961-1999)

Age of entrant	Death rate—unweighted (%)	Cumulative death rate—unweighted (%)	Death rate—weighted (%)	Cumulative death rate—weighted (%)
1	13.57	13.57	6.81	6.81
2	11.24	24.81	5.99	12.81
3	8.83	33.64	6.21	19.01
4	8.94	42.58	5.17	24.18
5	6.22	48.80	4.25	28.43
6	4.60	53.40	4.09	32.52
7	4.18	57.58	3.34	35.87
8	3.69	61.27	3.51	39.38
9	3.33	64.60	3.40	42.78
10	3.21	67.81	2.48	45.26
11	2.89	70.70	2.63	47.89
12	3.26	73.96	3.00	50.89
13	2.19	76.15	1.84	52.73
14	2.36	78.52	2.11	54.84
15	1.78	80.29	1.80	56.64
16	1.47	81.77	1.62	58.25
17	1.42	83.19	1.61	59.87
18	1.42	84.61	1.85	61.71
19	1.18	85.79	1.35	63.06
20	1.19	86.98	1.79	64.85
21	1.20	88.18	1.41	66.26
22	1.42	89.59	2.15	68.41
23	0.62	90.21	0.98	69.39
24	0.68	90.90	1.06	70.45
25	0.72	91.62	1.11	71.56
26	0.65	92.27	1.16	72.72
27	0.53	92.80	0.86	73.59
28	0.47	93.27	0.84	74.42
29	0.62	93.89	1.60	76.02
30	0.68	94.57	1.81	77.83
31	0.59	95.16	1.82	79.65
32	0.53	95.69	1.52	81.18
33	0.41	96.10	1.41	82.59
34	0.45	96.55	1.50	84.08
35	0.40	96.95	1.07	85.16
36	0.35	97.30	1.49	86.64
37	0.42	97.72	1.39	88.03
38	0.34	98.06	1.15	89.19

Note: Weighted estimates use employment.

Figure 1. Death rates

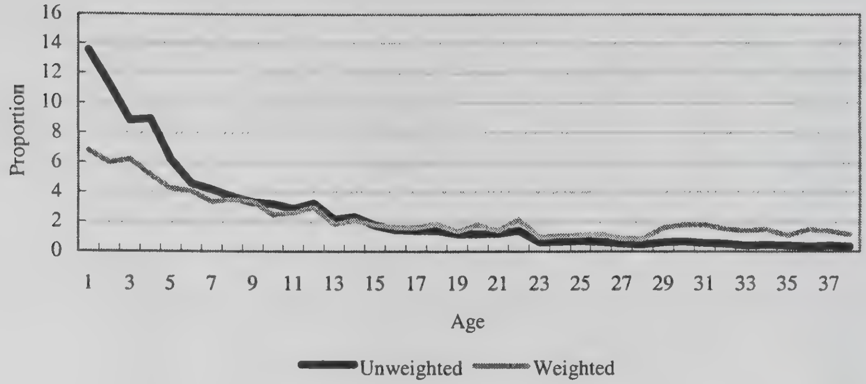
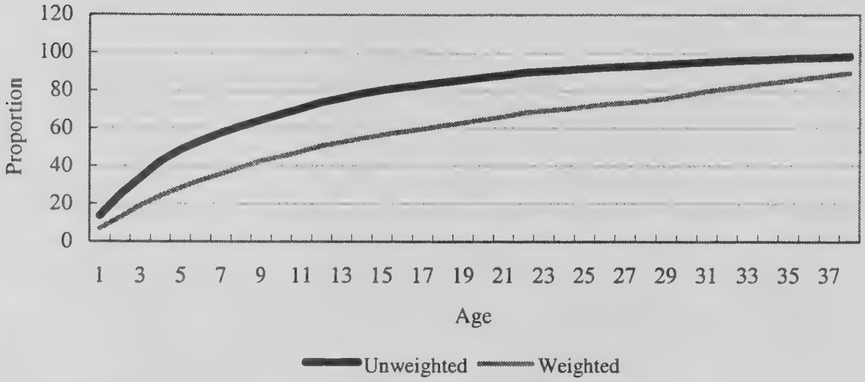


Figure 2. Cumulative death rates



High initial death rates suggest that the average new plant does not last long. This is indeed the case. The average length of life of a cohort is only 9.4 years (Table 2).

These rates vary by industry. The longest length of life (13 years) can be found in two industries—primary metals and paper and allied products. The shortest length of life (less than 8 years) is in the wood and furniture industries.

It is the new smaller plants that tend to fail most rapidly (Baldwin, Bian, Dupuy and Gellatly, 2000). This means that the rate at which new plants die is higher than the rate at which employment in new plants disappears. For example, the unweighted exit rate of new plants in their first year is 13.6%; but only 6.8% when weighted by employment. The unweighted cumulative rate of exit by age 5 is 49%, but only 28% when employment-weighted. By age 30, these rates are 95% and 78%, respectively. The unweighted and weighted exit rates are depicted in Figures 1 and 2, respectively.

Table 2. Average length of life of new manufacturing plants (years)

Industry	Unweighted mean	Standard error of mean	Weighted mean[a]
All	***9.4***	***0.02***	***16.5***
Food and beverage	10.1	0.07	18.4
Tobacco	14.3	1.02	23.3
Rubber and plastics	10.0	0.14	16.2
Leather and footware	9.8	0.24	15.5
Textiles and clothing	9.6	0.08	15.1
Wood	7.6	0.06	15.0
Furniture and fixtures	7.5	0.08	14.0
Paper and allied products	13.1	0.26	18.3
Printing, publishing	9.7	0.07	17.0
Primary metal	13.1	0.33	22.6
Metal fabricating	9.8	0.07	14.5
Machinery	9.8	0.12	16.0
Transportation equipment	9.2	0.12	19.1
Electrical and electronic products	9.4	0.12	14.9
Non-metallic mineral products	9.8	0.13	14.9
Refined petroleum and coal	10.4	0.49	16.2
Chemical and chemical products	10.5	0.14	17.4
Miscellaneous	8.8	0.08	13.3

[a] Weighted by total employment.

In order to make use of this information to predict how the death rate affects the length of life of capital, we should actually weight the death rate not by employment but by capital. Unfortunately, we do not possess capital per plant. But we can at least state that the unweighted mean length of life (Table 2, column 1) will underestimate the length of life for the average dollar invested, since investments are higher in larger plants. A better measure of the latter is provided by the employment-weighted mean length of life of entrants (Table 2, column 3). For the entire manufacturing sector, the mean length of life is some 16.5 years. In primary metals, it is 22.6 years. In furniture, it is only 14 years.[9]

5.2 Estimating the survival function

We can use a simple functional form to represent the process that leads to exit—and generate additional summary statistics to describe this process. The exit rates derived in Table 1 and the estimate of the length of life reported in Table 2 are calculated without the benefit of a rigorous examination of the underlying patterns in the data. For example, the average length of life may not be a good measure of central tendency if the distribution of discards is asymmetric. And there is evidence that it is not symmetric—with more plants closing earlier in their life than later.

For this purpose, we represent the exit rate for analytical expediency with a Weibull function. The Weibull is a two parameter function often found to represent the death rate in the population fairly well.[10]

9. To the extent that the capital/labour ratio increases as employment size of plant increases, a capital-weighted length of life would be a little higher than these estimates.

10. See Gellatly, Tanguay and Yan (2002).

The failure or hazard rate of a Weibull function is:

$$h(t) = \gamma\alpha(\gamma t)^{\alpha-1} \tag{1}$$

The corresponding survival rate of this function is:

$$S(t) = \exp(-(\gamma t)^{\alpha}) \tag{2}$$

The survival function can be transformed by taking logarithms of both sides into the equation[11]

$$\log(-\log(s)) = \alpha(\log\gamma + \log t) = a + bt \tag{3}$$

Solving gives

$$\gamma = \exp(a/\alpha) \text{ and } \alpha = b \tag{4}$$

The estimated parameters from a least squares regression of equation 3 are presented in Table 3. The function fits the manufacturing data extremely well (adjusted R^2 of over .99) and the coefficients for both the intercept and slope have t statistics over 145. The test for linearity that the regression must satisfy is met.

Table 3. Regression for Weibull function of survival process

	Coefficients	Standard error	t -stat	P-value
A	-1.16962	0.007328	-159.601	6.52E-53
B	0.866723	0.005937	145.9894	1.61E-51
R^2	0.998			

The average length of life of an exit process that follows a Weibull distribution is given by

$$[\Gamma(\alpha + 1/\alpha)]/\gamma \tag{5}$$

The value yielded by the regression is 4.14 years.

It is important to note that this estimate corresponds to the expected length of life—not the expected discard point of the plant (L) that is used in perpetual inventory exercises to measure capital stock. But there is a relationship between the two.

In standard estimates of capital stock, an estimate of the discard point (L) is derived from various sources, and then is used to estimate a depreciation rate. The simplest depreciation rate is calculated as 1/L. This straight line rate provides a constant dollar amount of depreciation per year but a progressively larger *rate* of depreciation over time. Alternately, a constant rate of depreciation (corresponding to a geometric rate of decay) is obtained by choosing a constant

11. See Baldwin, Bian, Gellatly and Dupuy (2000) for more detail.

(referred to as the declining balance rate—DBR) and dividing this by L (i.e., Depreciation=DBR/L). The DBR is generally set equal to 2 or higher.[12]

If we choose the rate 2/L, we generate a geometric rate of depreciation that closely approximates the Weibull in most situations. The expected mean length of life yielded by the geometric function is just L/2. If we therefore set our estimate of the expected length life from the Weibull (4.14) equal to that from the geometric (L/2), the equivalent value of L is just 2*4.14 or 8.3 years. Thus our Weibull form yields an expected discard point of about 8 years, compared to the value of 9 years that comes from taking a simple average of the discard points. The two estimates are quite similar.

An alternate route to estimating the expected length of life and the discard point of an asset (either machinery or a plant) involves the use of data on the prices of used assets.[13] By examining the price profile of used assets, the depreciation rate, its functional form and the discard length of life can be estimated. In a recent Canadian study, estimates of these parameters were obtained (Gellatly, Tanguay and Yan, 2002, p. 51). The implicit weighted discard period that the econometric price method yields is around 22 years.[14] Since these estimates are weighted, the equivalent estimate from our plant death data is 16.5 years (Table 1, column 3).

These differences are the result of quite different implicit assumptions. When we examine the death rate of plants and use it to derive depreciation rates and length of life, we must implicitly assume that the death of a plant corresponds to a complete loss of value. This is probably incorrect. The proportion of value that will be lost depends on whether the investment is sunk, that is, the extent to which the investment can be physically moved or adapted to alternate uses. Ramey and Shapiro (2001) show that even movable machinery and equipment loses a substantial amount when sold. Buildings are likely to lose even more when a manufacturing plant's operations are terminated and the building sold. Buildings are rarely moved. And while they can be adapted to other uses, the process is costly.

Because of the differences in the assumptions used in the two methods, we should expect the discard length of life calculated from plant deaths to be less than the discard point when calculated from the price of used buildings. That there is so little difference between the death rate estimates of discard points and the price estimates suggests that a large proportion of the value of a plant is lost when it is closed down.

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12. Choosing a value of 2 ensures that the expected value of the geometric process will just equal that associated with the straight-line process
13. See Gellatly, Tanguay and Yan (2003).
14. A recent Deloitte and Touche (2000) study in the United States that uses prices of buildings found that the length of life of industrial buildings was about 20 years—very close to our own estimates.

6. Conclusion

Manufacturing plants have relatively short lives. Over half of new plants die by the age of 6. By the age of 15, less than 20% are still alive. The average new plant only lives 9 years (16 years if we calculate an employment-weighted average).

The high rate of plant death has several ramifications. First, and most immediate, is its impact on labour markets. A job within one production facility is not likely to last a lifetime. And where shutdowns occur, change and dislocation for employees is to be expected. When the death of a plant is the result of the death of a firm, the associated dislocation for workers is greatest. Some plant closings will also come from continuing firms and here, there is at least the potential for relocations of workers to other plants within the same firm—but relocation costs can be substantial even here if the new plant is located in other geographic areas.

High plant death rates have implications for the policy process both at the local and the national level. At the local level, economic development experts must be constantly working towards the replacement of the plants that they succeed in attracting—because new plants have high death rates. The building of a new plant is not likely to provide benefits for extremely long periods. While examples can be given in the auto industry or in the steel industry of plants that have not exited for very long periods, these are the exceptions to the norm.

At the provincial and national levels, industrial policy needs to be cognizant of the rate of turnover. Because of high rates of plant closure, the health of the manufacturing sector depends on the rates of renewal—in this case in the form of entry of new plants. And new plants are presumably encouraged by incentives and discouraged by disincentives. For example, a tax policy that discourages new investment will be felt much more quickly in a world where plants are constantly exiting the market place and being renewed—because less renewal that is occasioned by a burdensome tax environment will quickly translate into a smaller sector and fewer jobs. This paper has stressed that the industrial system is not comprised of behemoths whose inertia allows for considerably prodding before movement occurs.

High death rates also have implications for the statistical system and macroeconomic models. Death removes productive capital from production. When long lives are adopted to transform past investment expenditures into estimates of the amount of capital available today, the capital series tends to be smooth and does not vary considerably across the business cycle. When shorter lengths of lives are used, the estimated capital stock will be smaller and more cyclical. With long lived capital, capital stocks are rarely related statistically to economic aggregates that tend to fluctuate with short cycles. With shorter asset lives, they will be. Therefore, obtaining accurate estimates of the length of life of an investment is critical if correct estimates are to be made about the relationship between productive capital and other macroeconomic variables.

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